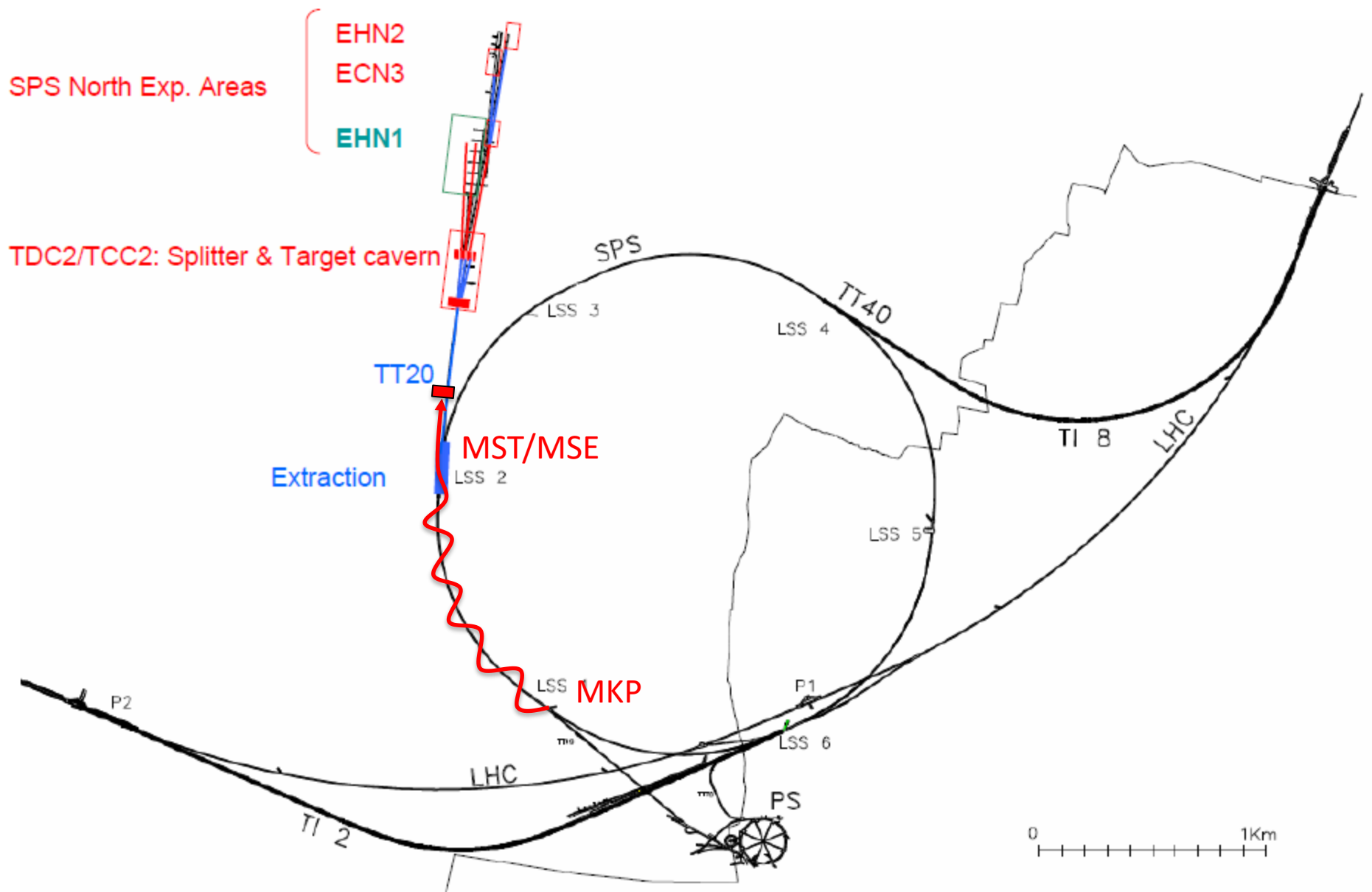# Beam transfer for NA neutrinos:
Extraction from SPS

B. Goddard, F.Velotti, A.Parfenova, R.Steerenberg, K.Cornelis, W.Bartmann, V.Kain, E.Carlier, A.Alekou, M.Meddahi, L.Jensen V.Mertens,
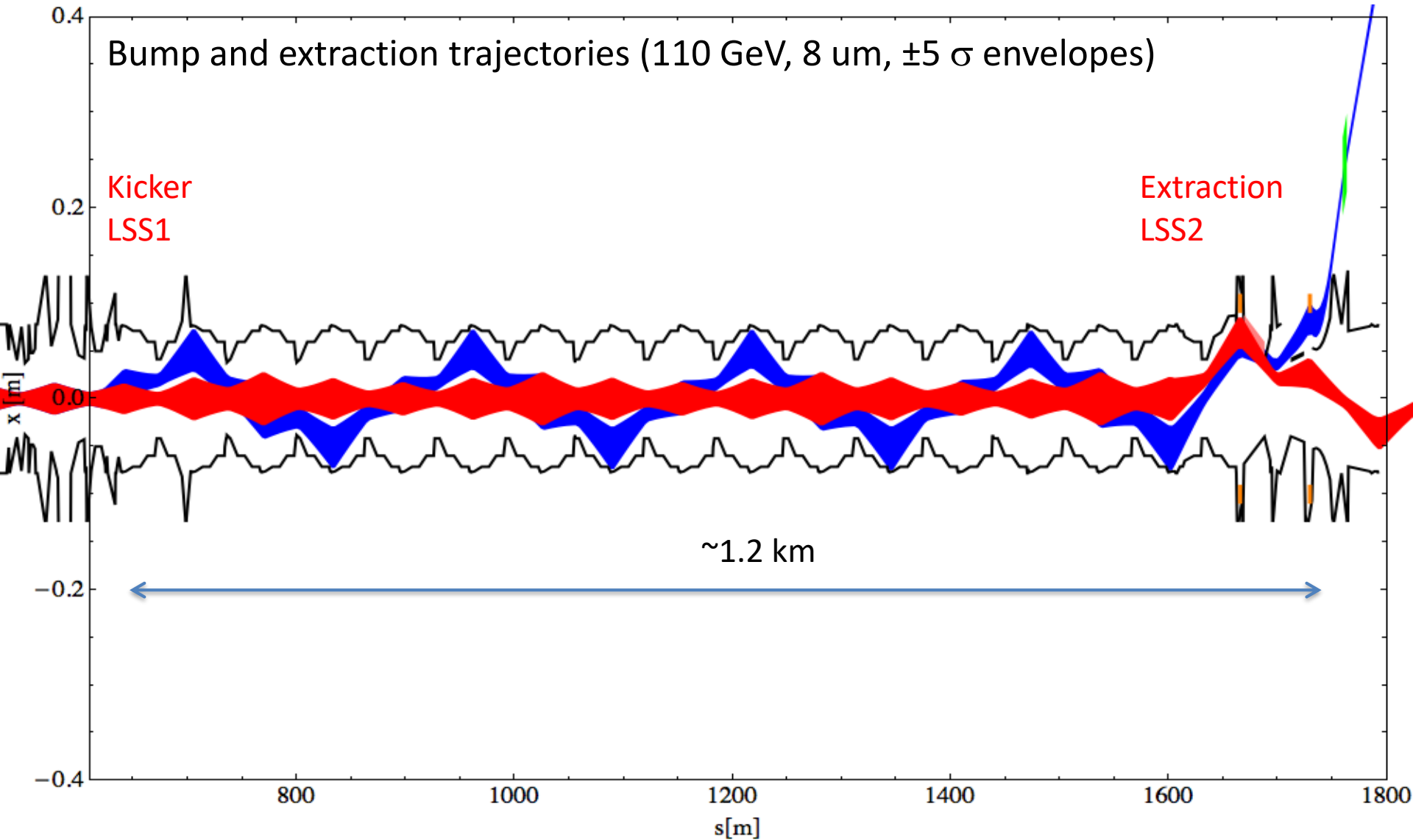
A.Kosmicki, J.Osborne, I.Efthymiopoulos

Extraction feasibility studies – Non-local extraction kickers

- Reminder: very difficult to integrate kickers into LSS2, so exploring the idea to use other SPS kickers :
  - LSS2 extraction using LSS1 MKP kicker (limited to ~100 GeV)
  - LSS2 extraction using LSS6 MKE kicker (up to 450 GeV)
  - LSS2 extraction using LSS4 MKE kicker (up to 450 GeV)
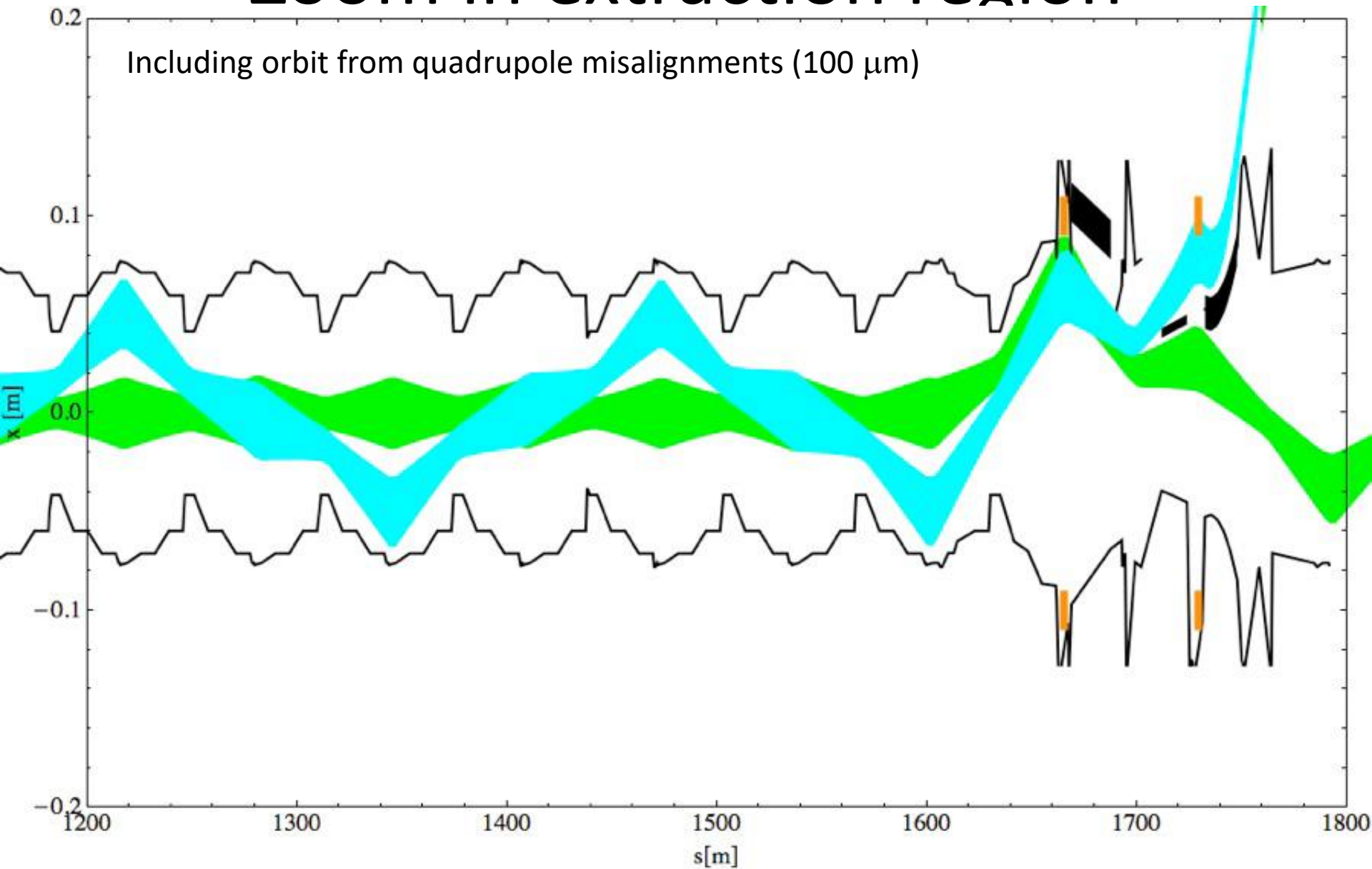   - In reserve…

- Concentrated so far on extraction with LSS1 MKP

Non-local extraction kicker
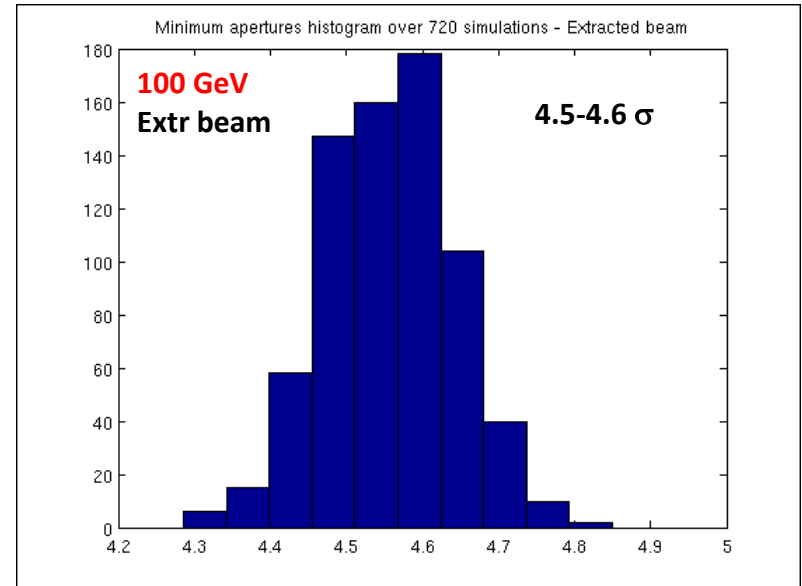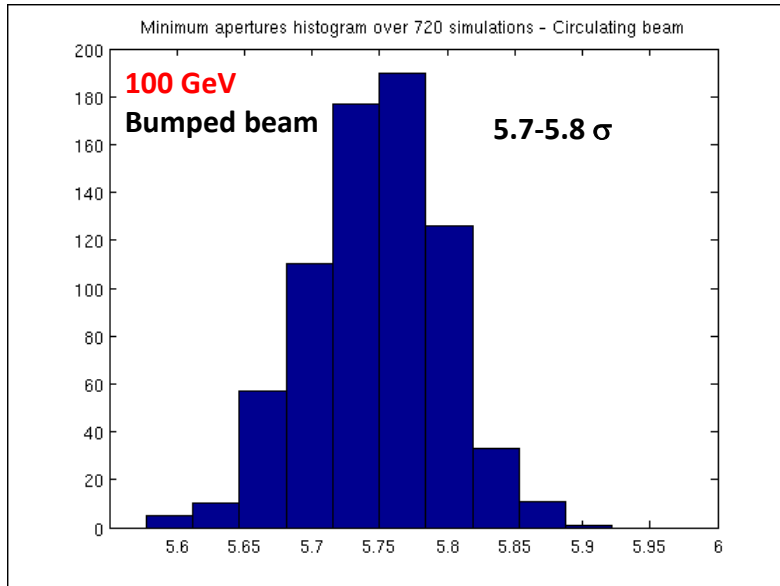
Simulations – LSS1->LSS2

Bump and extraction trajectories (110 GeV, 8 um, ±5 σ envelopes)

Kicker
LSS1

Extraction
LSS2

~1.2 km

Zoom in extraction region

Including orbit from quadrupole misalignments (100 μm)

Aperture quantification, with SPS orbit

Minimum apertures histogram over 720 simulations – Circulating beam

110 GeV
Bumped beam

5.1-5.2 σ

Minimum apertures histogram over 720 simulations – Extracted beam

110 GeV
Extr. beam

3.7-3.8 σ

Minimum apertures histogram over 720 simulations – Circulating beam

100 GeV
Bumped beam

5.7-5.8 σ

Minimum apertures histogram over 720 simulations – Extracted beam

100 GeV
Extr beam

4.5-4.6 σ

Many aspects still to be considered

- Kicker upgrade + timing + controls
  - Extraction pre-pulse, double extraction a la CNGS, BETS
  - Timing destination
 - …
- BI in transfer line and extraction region working for slow and fast extracted beam

- Machine protection – interlocking
  - SPS ring and lines

- For the time being no show stopper.

- Time line: first beam in 2017

Critical aspects specific to LSS2FE

- Accidental large orbit bumps in the SPS arc
- Phase advance changes
  - Measurement of amplitude dependence of phase advance: negligible

- The machine protection system must protect against these

SPS measurements (I) 4/09/2012: LSS1 – LSS2 phase advance checks
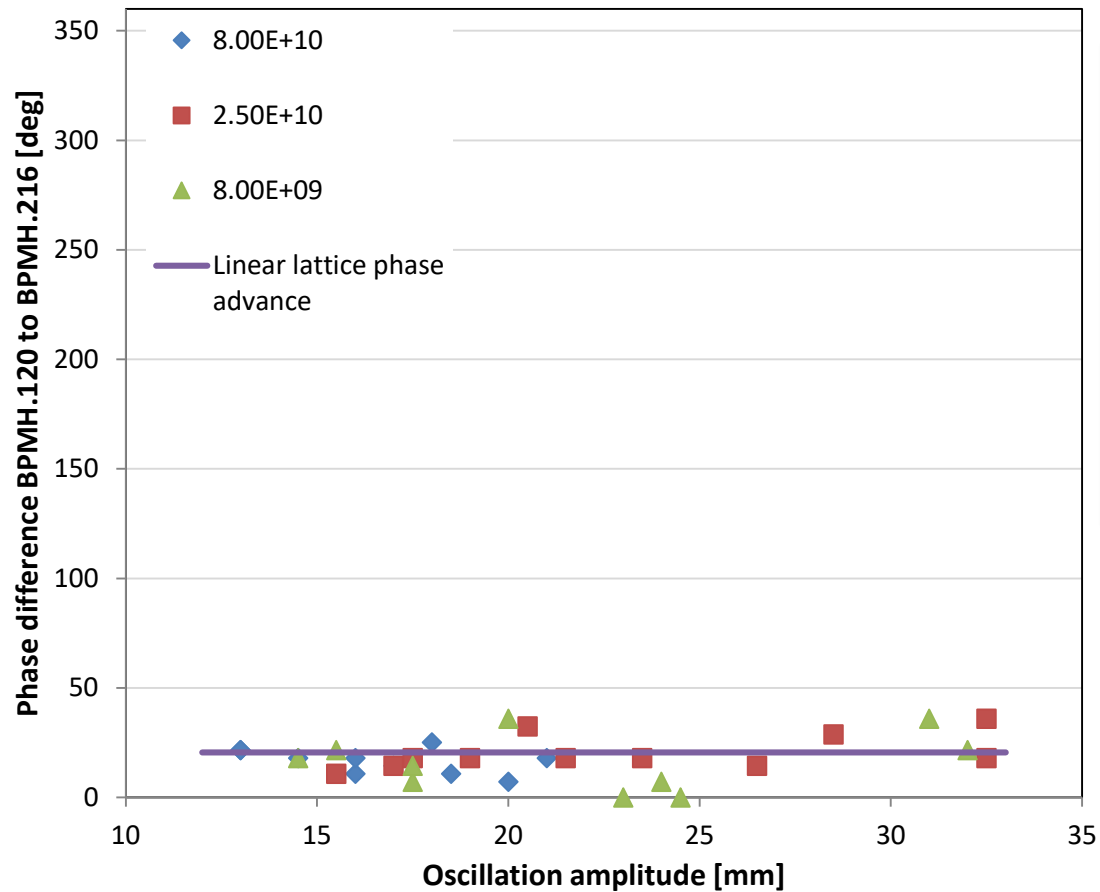
- Phase advance scatters within ±15° around value expected from linear lattice (20.5°)

- No tune dependence on oscillation amplitude or intensity

Interlock Controllers a la LSS4/LSS6 (1)

- ## LSS1 – "straight forward" conceptually
  - ### Master BIC for MKP:
    - Decides between injection and LSS2 extraction

1	E–440 Flag	FALSE
2	E–450 Flag	FALSE
3	TT60–A	FALSE
4	TT60–B	FALSE
5	TED–in TT60	TRUE
6	TT66–A	FALSE
7	TT66–B	FALSE
8	TI2 Upstre...	FALSE
9	TI2 Downs...	FALSE
10	TED–in TI2	TRUE
11	INJ Beam–1	FALSE
12	Probe Bea...	FALSE
13	BPF–1	FALSE
14	SBF–1	TRUE

LSS6 Master BIC

1	E<=26 GeV	FALSE
2	E-100 Flag	FALSE
3	SPS permit ?	FALSE
4	True	FALSE
5	False	TRUE
6	TT10 - A	FALSE
7	TT10 - B	FALSE
8	TT20 - A	FALSE
9	TT20 – B	FALSE
10	SBL	TRUE
11	True	FALSE
12	True	FALSE
13	True	FALSE
14	True	TRUE

SPS permit
could also only
go into TT10

Interlock Controllers a la LSS4/LSS6 (2)

- Local "slave" BICs
- Cables from LSS2 to LSS1 for slave BIC results
- Need to define which equipment to interlock:
  - Bumpers, septa, ZS out, orbit bump for circulating beam with BPMs
  - Transfer line power converters, trajectory, BLMs
  - Target
  - Orbit in arc(s) between kicker and LSS2. SIS? Only orbit correctors or orbit reading as well?
  - Tune/ phase advance. Interlock power converters for QF or QF1 and QF2 if tune split needed.
  - Intensity interlock: tune shift

Extraction kicker in LSS6

- Study should cover Short Base Line Neutrino Facility (100 GeV) AND Laguna (400 GeV)

- MKP does not give enough kick at 400 GeV
  - Rise time < 1 us, 11 us flattop
  - OK for double extraction

- MKE LSS6 kick up to 450 GeV
  - Rise time 6-7 us
 - Not OK for double extraction ➔upgrade needed

LSS6 crowded

- LSS6 master BIC full.
  - Daisy chain of slave BICs to combine entries?
  - Change of master BIC equation
  - Details to be investigated

- There is also AWAKE

TESTS WITH BEAM

LSS1 – LSS2: MD with pilot/indiv

- 17/9/2012

- 110 GeV cycle

- LHC pilot, indiv

- Aperture checked, fine
  - 7 um emittance

Acquisition of last turn.

BTV.210026 BTV.210352
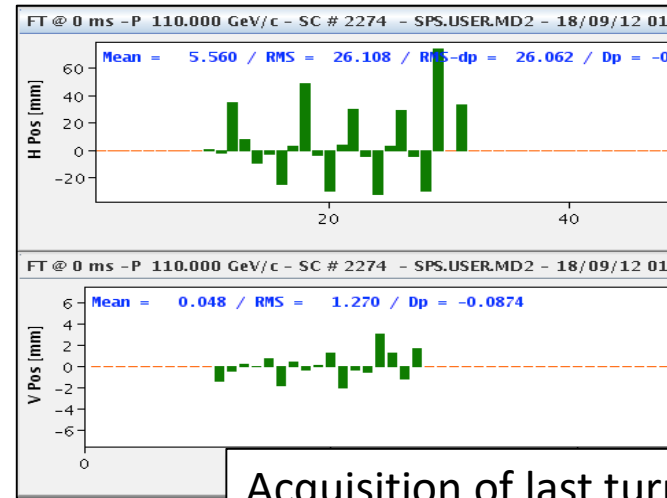
Test was successful!

Further tests planned

- LSS1 – LSS2, 100 GeV: low intensity fixed target beam
  - Aperture checks

- LSS6 – LSS2, 440 GeV: HiRadMat cycle, with HiRadMat destination, pilot beam.
  - Mask bumpers to be able to zero extraction bump
  - Check aperture bottleneck in LSS1 (at dumps)

- No test planned for LSS4

- No interlocking modifications required in 2012

Summary

- Non-local extraction works on paper and in the machine
  - …at least with low intensity
  - More tests to come this year
- Two options investigated:
  - MKP: 100 – 110 GeV, double extraction possible, but RCPS upgrade needed
  - MKE LSS6: 400 GeV, only single extraction for the time being
- Machine protection
  - conceptually more straight forward for LSS1
  - should be able to find solution for LSS6 as well
  - Interlocking on orbit and orbit correctors critical
  - Non-local extraction ➔ long cables
  - LSS2/TT20 equipment (instrumentation and power converters) needs upgrade to be interlocked

EXTRA SLIDES

Phase advances – 2012 optics

LSS1->LSS2: LHC Q26

- lss1_deltamu =   4.1895 (68.22 deg) ;

- kick_2 =   0.929 ;

LSS6->LSS2: CNGS

- lss6_deltamu =   9.0675 (24.29 deg);

- kick_6 =   0.411 ;
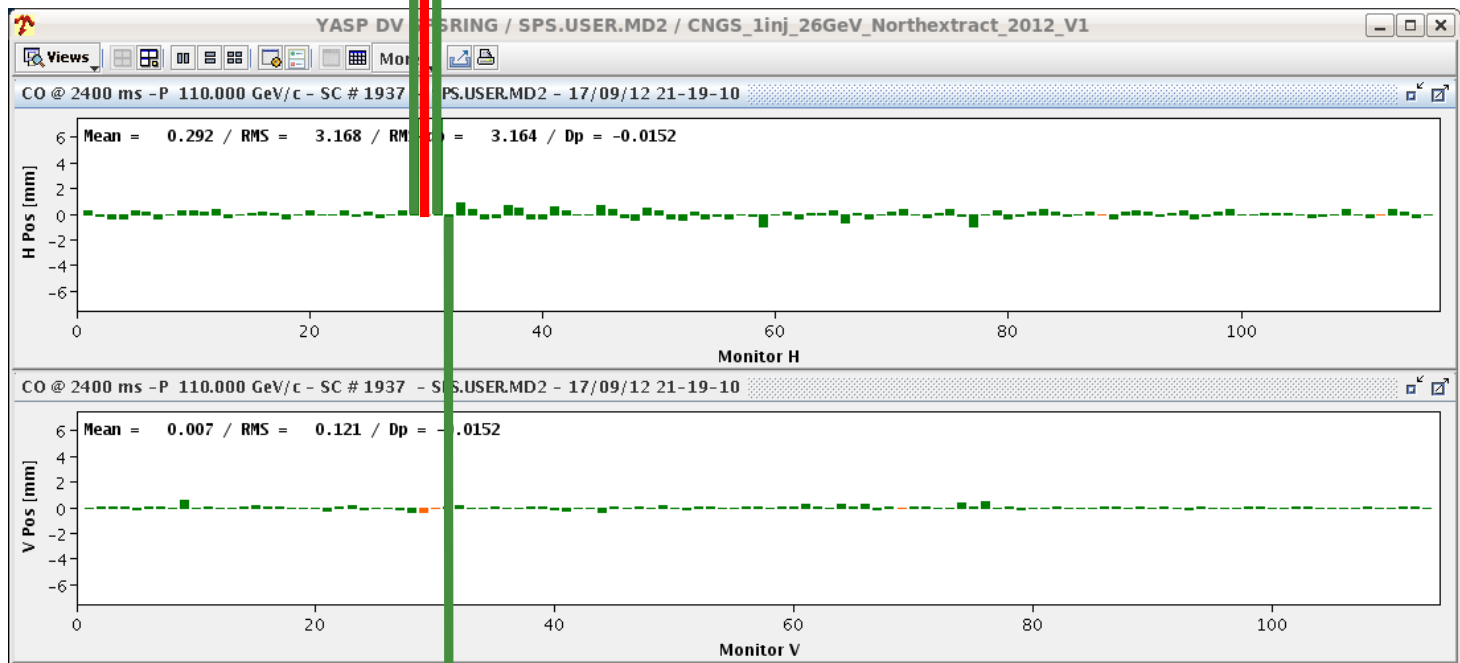
LSS6->LSS2: LHC Q26

- lss6_deltamu =   8.8998 (323.94 deg);

- kick_6 =   -0.589 ;

LSS6->LSS2: LHC Q20

- lss6_deltamu =   6.8491 (305.60 deg);

- kick_6 =   -0.812 ;

B.Goddard

LSS2 closed orbit bump

- New bump shape with huge 60 mm excursion in QFA216
- Very small leakage (rms ~0.3 mm) – no losses or issues

Aperture and loss scans

- 4e11 p+, 110 GeV, blown up to 7 um.mrad to approach CNGS parameters

- Issue seen with too-fast bumper functions, corrected